

BENEFIT POTENTIAL OF ESP IN REAL ACCIDENT SITUATIONS INVOLVING CARS AND TRUCKS

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ABSTRACT

The Electronic Stability Program, or ESP, for passenger cars, leads to a stabilization of the vehicle in adverse circumstances on the road or during evasive maneuvers by means of a selective intervention in the braking system and the resulting regulation of the yawing moment. This is of particular importance during evasive maneuvers, when counter-steering and when accelerating or decelerating during cornering. Furthermore, stability control systems such as this are about to be released on to the market for commercial vehicles. In conjunction with additional roll-over preventing systems, this represents real potential in the avoidance of accidents, in particular rollover and dangerous jack-knifing.

In this context, the Institute for Vehicle Safety Munich (IFM) investigated the benefit potential of ESP in real accident situations by means of a detailed analysis of several accident databases. On the one hand, they determined the maximum possible benefits and on the other hand they analyzed and categorized individual accidents where ESP could exert a positive influence. Loss of control could be observed in approx. 25 to 30 % of all car accidents involving personal injury. In the case of trucks, up to 9% of serious accidents could have been positively influenced or even prevented using an ESP.

Finally, limitations of these modern technical systems will be outlined and possible future problems such as poor maintenance will be discussed.

THE ACCIDENT SITUATION IN EUROPE AND GERMANY

Between 1990 and 2000, the number of recorded deaths due to traffic accidents in the European Union fell dramatically from 56,400 to around 41,900 [1]; a reduction of around 25 %. Of course, the number of victims is still too high. Statistically speaking, around

115 people die in road traffic accidents in the 15 EU member states every day and just under 7,400 are injured (Figure 1).

Faced with the still unacceptable numbers of victims in road traffic, the European Commission set itself a "justifiably" very ambitious target in its White Paper [2]. It aims to halve the number of fatalities in road traffic in the period between 2000 and 2010. If this goal is achieved, the lives of more than 20,000 people will be saved annually as of 2010. If, in addition, a linear reduction in the total number of fatalities is assumed, around 100,000 lives could be saved by 2010.

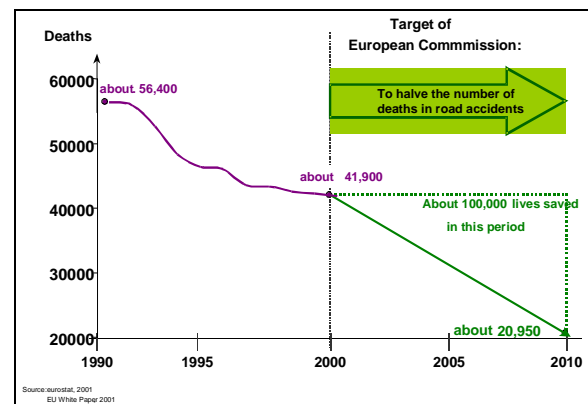


Figure 1. Development in the number of road accident deaths in Europe (harmonized data) showing the target of the European Commission by 2010 [1;2]

From the point of view of accident research, safety measures must be applied in those areas where the greatest benefit can be expected in order to achieve this goal. The importance of ESP for commercial vehicles and passenger cars in this context will be dealt with below. Firstly, let us have a look at federal statistics for Germany.

In recent years, there has been a positive trend in the rate of accidents in Germany: The number of accidents with fatalities is on the decrease [3]. This decrease is particularly marked among car occupants, although they still account for around 60 % of all road users who are killed. A look at the total number of accidents, however, or the number of people injured or killed, reveals that the absolute number has remained virtually static over the last few years (Figure 2).

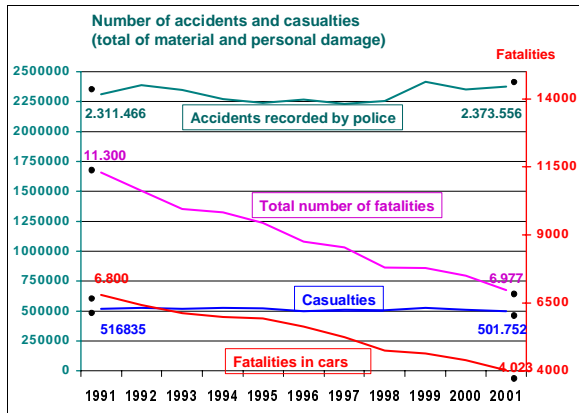


Figure 2. Development in the numbers of accidents, casualties and fatalities in road traffic between 1991 and 2001 [3]

The increase in the annual mileage [4] and the number of vehicles [5] on German roads in recent years, has resulted in a relative reduction in accident risk. This reduction, however, is significantly lower than the reduction in accidents with serious injuries or fatalities in cars. This means that the positive trend with regard to accidents is attributable much less to the prevention of accidents overall than to the prevention of serious personal injuries in accidents (and hence to passive safety). This trend will continue over the next few years as the number of new vehicles with optimized passenger cells/crumple zones and above all equipped with airbags increases.

In-depth accident analyses also clearly show the effect of improved protection in the event of front-impact collisions. Today, more accidents with serious injuries/fatalities of car occupants (MAIS 3+) occur with side-impact collisions than with front-impact collisions. 60 % of car occupants who were killed were involved in side-impact collisions [6].

A precise analysis of the side-impact collisions with serious injuries or fatalities revealed that accidents which occur at crossroads or junctions are not the most important factor here. Rather, the most dangerous side-impact collision is when a car skids and slides¹ onto the opposite side of the road as a result of an excessive steering response and is involved in a front to side impact collision there (Figure 3). Yet it is not only car-to-car collisions following a skid of this type that result in the deaths of the occupants of the car hit side-on. The number of fatalities in single-vehicle accidents where cars skid

against trees is considerably higher (Figure 4). Designing intelligent technical systems to prevent this type of skidding is therefore a measure of the utmost priority.

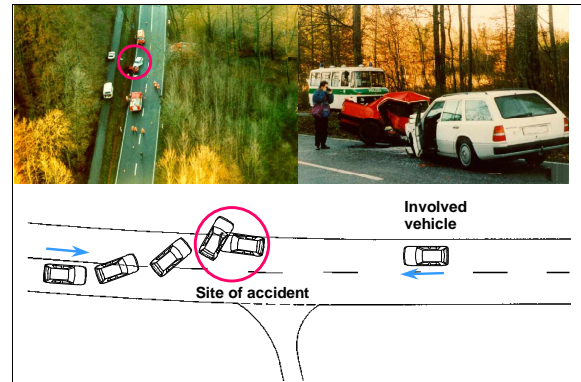


Figure 3. Example of a fatal car to car collision after skidding

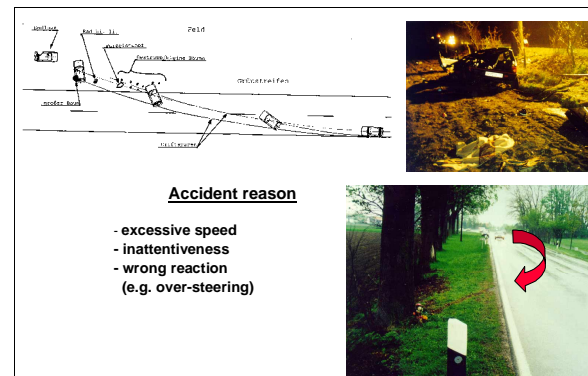


Figure 4. Example of a single accident where the skidding car being out of control crashed into a tree

ANALYSIS OF DRIVER ASSISTANCE SYSTEMS

The recent development of electronic stability programs, known as ESPs [7], provides today's drivers with support in stabilizing their vehicles. The handling of the vehicle, i.e. the difference between the intended path and the actual path of a vehicle, is constantly monitored and the stabilizing effect of the system is automatically activated when destabilizing effects occur, such as sudden changes in traction due to cornering quickly, evasive maneuvers etc. (Figure 5).

Oversteering, or jack-knifing in the case of a semitrailer, for instance, is prevented by automatically braking the front wheel on the outside of the corner, and the trailer.

¹ Throughout the remainder of this paper, the term "skidding" will be used to refer to skidding and sliding sideways

The central issues for accident research are:

- What proportion of all accidents involve skidding?
- What are the characteristic sequences which occur during the pre-crash phase?

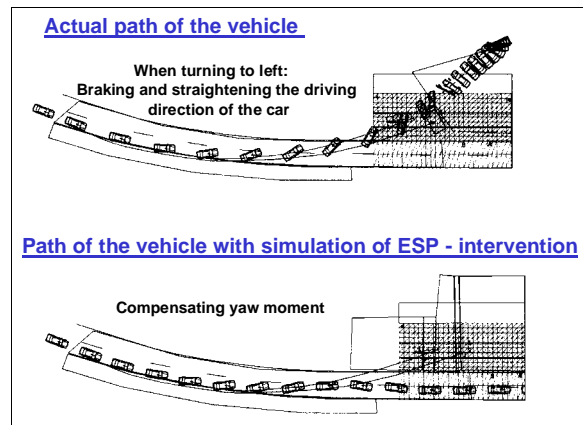


Figure 5. Example of an accident due to skidding with ESP-intervention

This question can only be answered by accident material analyzed according to engineering criteria – official statistics are of insufficient use for this purpose. Official accident types do reveal, however, that around a third of accidents with personal injuries is accounted for by driving accidents in which drivers have lost control over their vehicle without an encounter with another road user (Figure 6). However, even in the case of accidents in or against the direction of travel, skidding is often the cause.

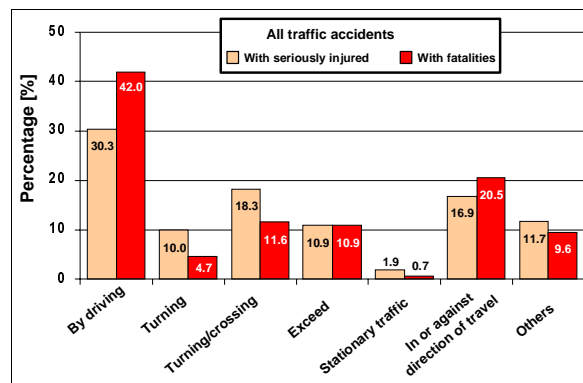


Figure 6. Accident types in federal statistics [3]

The accident research unit of the German motor vehicle insurance industry provides several independent sources of accident material to investigate this issue. Accidents were investigated in an interdisciplinary effort by engineers and physicians with regard to both the course of the

accidents and the type of collision, and the consequences of the accidents, such as damage to vehicles and injuries. Figure 7 displays the information recorded by GDV's accident research unit. Approximately 400 parameters are used per accident.

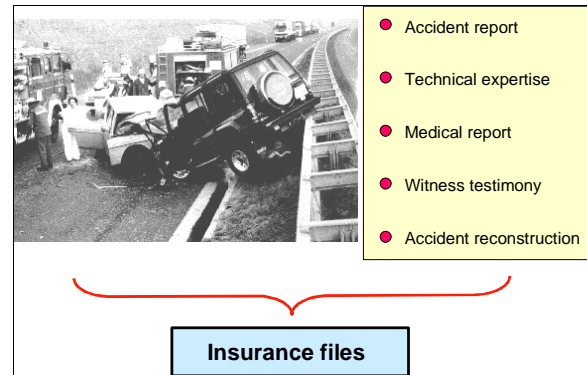


Figure 7. Accident data sources of the German insurer industry

The following accident material is available for analyzing "accidents with skidding" (Figure 8). In a representative survey taken from claims made to all German insurance companies, 15,000 car-to-car accidents and 1,000 single-vehicle car accidents were analyzed retrospectively [8]. This material was used for an in-depth analysis of all cases involving serious injuries or fatalities among occupants (MAIS 3+) [6]. These 1,100 car-to-car accidents and 524 single-vehicle car accidents provide information on pre-crash characteristics. This material thus covers a representative distribution of drivers (those responsible for accidents and innocent victims) from all age groups and all types of car accident, but only includes the most serious accidents.

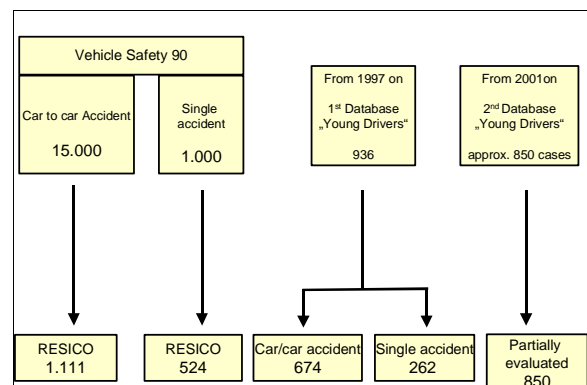


Figure 8. GDV accident databases [6;8]

We were also able to obtain information on the pre-crash phase from another, independent database. In the region covered by a single police force

(Traunstein), every car accident involving a young driver (936 accidents in total) was recorded [9]. This material covers all types of collision including accidents resulting in minor injuries, but it is restricted to young drivers, who are known to be at a greater risk of involvement accidents with skidding.

This is currently being supplemented by a database on young drivers compiled from around 850 accidents in the year 2000. In a similar way to the independent database, this material will also be used to examine all types of collision in accidents with personal injuries involving young drivers [10].

POTENTIAL BENEFITS OF ELECTRONIC STABILITY PROGRAMS FOR CARS

A comparison of these three independent sources of accident material can be used to estimate what proportion of accidents involve skidding. Further representative surveys are planned on this basis.

In order to describe vehicle handling in the pre-crash phase, a new kind of methodology was developed for "critical situations" (Figure 9). A graph was used to characterize:

- If there was, and if so what form of, skidding during the pre-crash phase
- Whether there was a simple skid or whether multiple steering correction attempts were made
- What the braking reaction of the driver was and
- What the length of the overall incident path was.

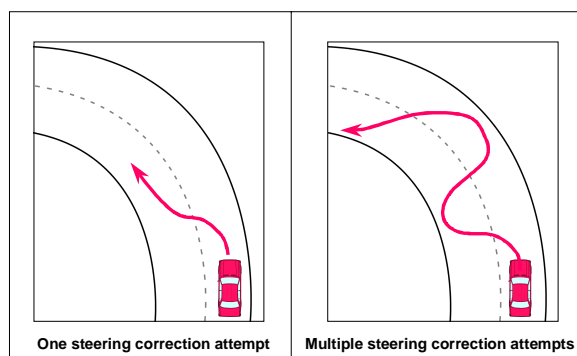


Figure 9. Description of critical driving maneuvers prior to the accident

Figure 10 gives a practical example of a skid accident. After cornering too quickly, the driver skidded and collided side-on with oncoming traffic.

In the "RESICO" database or the first database on "Young Drivers", between 40 and 60 % of single-

vehicle accidents involved skidding, and more frequently for young drivers than for drivers from all other age groups. It can be assumed that around 12 % of car-to-car accidents with personal injuries will involve skidding. A first ad-hoc analysis of the second database for "Young Drivers" indicates that around 27 % of accidents involve skidding. In relation to the total number of car accidents, we can assume that a much higher proportion of accidents involve skidding (at least 20 to 25 %) than was previously thought (Figure 11).

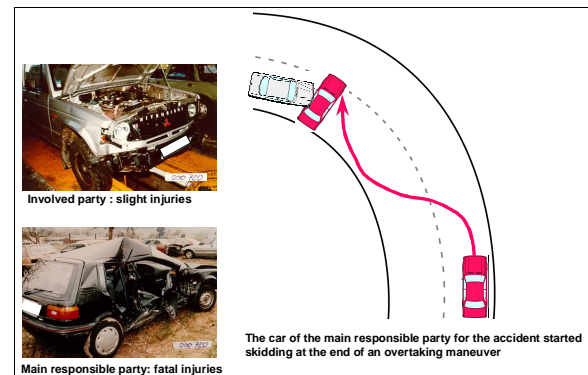


Figure 10. Typical accident situation: side collision due to skidding

Special studies also show that the number of accidents involving skidding increases dramatically in proportion to the seriousness of the accident: In the case of fatal accidents, the number of accidents involving skidding can be assumed to be at least 30 %, possibly even 40 %.

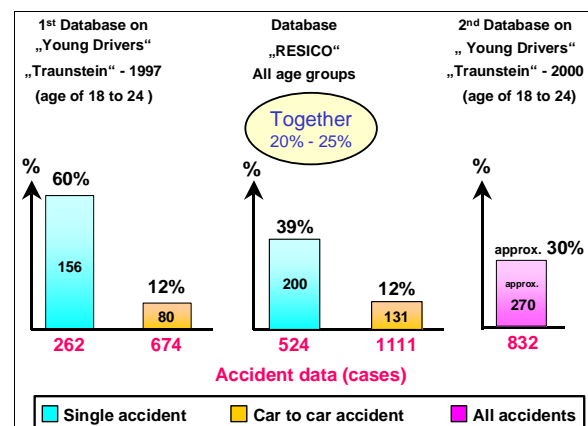


Figure 11. Accidents with skidding broken down by different data sources [6;9;10]

Further studies need to be carried out on this aspect. The clear message, however, is that driver assistance systems which reduce accidents involving skidding and improve stabilization of the vehicle would have a

positive influence on a significant number of serious accidents.

30 to 40 % of accidents involving skidding occurred on straight stretches of road. Skidding is considerably more common in or after bends, as expected. In the case of bends, the question is whether or not the physical boundaries with regard to lateral acceleration were exceeded. No driver assistance system can of course change the physics of vehicles in motion, they can merely improve stabilization below the threshold level. The accident material showed that around 40 to 50 % of cars left the road on the inside of the bend and thus were still below the threshold for the bend. The accident was thus attributable to an excessive steering response and not to the physical threshold values being exceeded.

If we combine the accidents involving skidding on straight stretches of road and on bends, 60 % of these cases are the result of a driver error below critical levels, or to an excessive steering response. An appropriate electronic stability program could at least have a positive impact on these accidents and perhaps even prevent them.

Of course, the behavior of the driver plays an important role. Having less experience, young drivers far more rarely make multiple correction attempts than the drivers in the "RESICO material" which includes all age groups. Young drivers typically lose control of their vehicles in bends after just a single correction attempt, and then collide with oncoming traffic or with other objects. The results show, however, that a large proportion of experienced drivers (around 70 %) attempt to stabilize the vehicle with a number of corrective steering maneuvers (Figure 12). One can expect that there is a far greater chance of regaining stability in vehicles equipped with ESP.

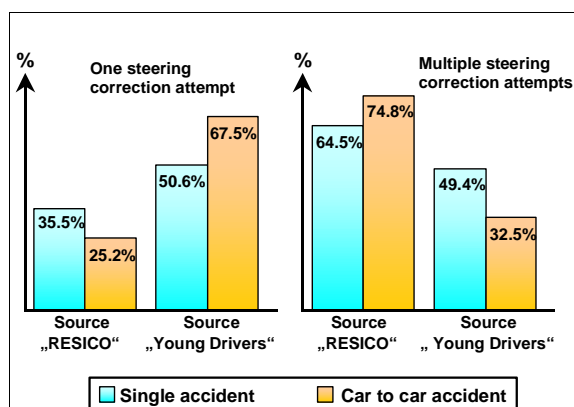


Figure 12. Distribution of cases broken down by data source, accident type and number of steering correction attempts [6;9]

The braking behavior of the driver during the critical pre-crash phase also significantly influences the stabilization options (Figure 13). The investigation confirmed once again that only 50 % of drivers braked before the collision – they attempted to stabilize the vehicle with steering maneuvers during the skid. Full braking was only evident in 30 to 40 % of cases, where the higher of the two values applied to car-to-car collisions. Braking was generally less common on bends than on straight stretches. This lower proportion of emergency braking would further increase the possibilities of lateral stabilization for electronic stability programs (ESP), namely by targeted intervention at the wheels.

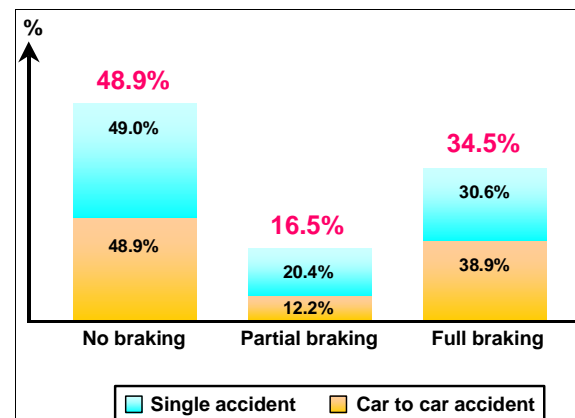


Figure 13. Distribution of cases broken down by kind of braking maneuver

POTENTIAL BENEFITS OF ELECTRONIC STABILITY PROGRAMS FOR TRUCKS

According to an extrapolation by the European Working Group EEVC WG 14 [11], 16 % of fatal accidents – or about more than one in six – involve trucks with a gross vehicle weight of 3.5 tonnes and over. Accidents involving trucks therefore offer considerable potential for reduction to help achieve the EU Commission target. In order to reach that ambitious objective, in line with the Pareto principle action must be targeted on those areas which promise the greatest benefits. So the role of accident research is to define the required decision-making criteria with respect to active and passive safety.

In this context, the Institute for Vehicle Safety of GDV (German Insurance Association) participated at the initiation of a study to determine the potential benefit of commercial vehicle ESP systems which are either already available or currently being developed. The first step was to investigate the design, mode of operation, and possible effects of ESP systems in trucks. In addition, the possibility of avoiding or

mitigating accidents with ESP systems was analyzed on the basis of 850 severe accidents involving trucks. In the process, it was necessary to analyze specific accident situations which could potentially have been influenced by ESP.

RETROSPECTIVE ACCIDENT ANALYSIS

Accident database

The accident avoidance potential of ESP was assessed on the basis of data of all serious accidents involving trucks (with a gross vehicle weight [GVW] of 3.5 tonnes and over) in Bavaria in 1997 (850 cases). On the basis of experience with previous studies and the volume of data available from police accident reports, only accidents involving death or serious injury were taken into consideration. Of the total of 1,009 relevant accidents, 850 which directly involved trucks (i.e. single-vehicle accidents and collisions between trucks and other road users) were considered in detail.

The proportion of Germany's truck accidents that occur in Bavaria (17.1 %) is largely in line with the state's proportion of German roads (18 %) and its contribution to the surface area of the nation as a whole (19.3 %) [3]. Combined with further studies carried out to confirm the representative nature of the data [12], it is possible in a first approximation to extrapolate the truck accident situation to Germany as whole - at least in the field of vehicle safety.

Findings

A total of 917 trucks (GVW ≥ 3.5 t) were involved in the 850 accidents considered, including 198 (21.6 %) semitrailers, 263 (28.7 %) truck-trailer combinations and 456 (49.7 %) solo trucks.

Each individual accident was investigated to determine the possible positive effects of ESP. Based on information from sources such as police accident reports, accident reconstruction studies, tachograph charts and photos, the study looked into whether the physical conditions (speed and road conditions) were such as to allow successful intervention by ESP, and whether an ESP system could have prevented the accident or mitigated its effects.

This analysis showed that 73 or 8.6 % of the 850 accidents studied were "ESP-relevant". In these accidents, a total of 15 people were killed (2 in trucks and 13 in other vehicles) and 78 seriously injured (46 in trucks and 32 in other vehicles). Fig. 14 shows the types of trucks involved and the share of each type in ESP-relevant accidents. The vehicles concerned

included 19 semitrailers, 21 truck-trailer combinations and 33 solo trucks.

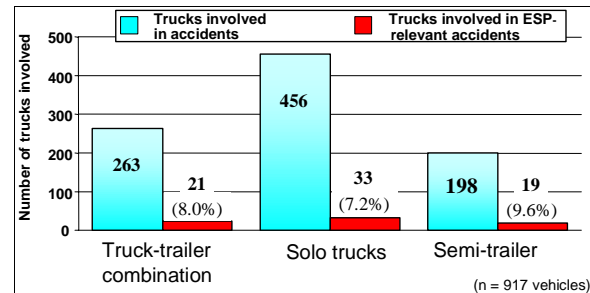


Figure 14. ESP-relevant accidents by types of truck

The 73 accidents found to be ESP-relevant were investigated to determine the primary cause and assigned to six categories (Figure 15). Accidents caused by a chain of circumstances were classified by the highest-priority cause on the basis of the information available. The main causes of these accidents included abrupt steering maneuvers following inattentiveness, skidding after collisions, excessive speed for the weather conditions, and skidding when cornering.

It is striking that some 50 % of ESP-relevant accidents occurred on roads that were not dry (on damp, wet, snow-covered or icy surfaces), although some 67 % of the total number of accidents studied (850) took place on dry roads. In addition, approximately 70 % of the truck drivers took defensive action, such as braking and/or steering, in the pre-crash phase.

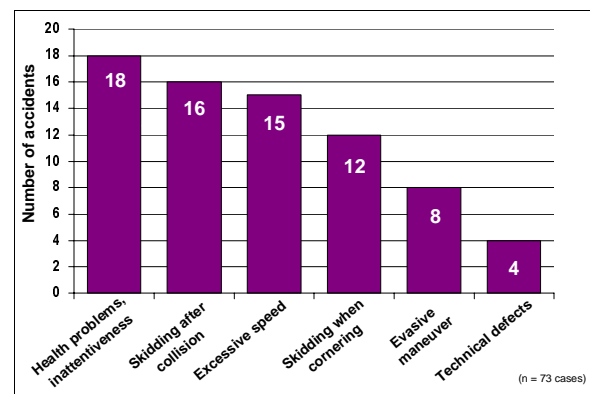


Figure 15. Classification of serious truck accidents by the primary causes of accidents

Finally, the study showed that the majority of accidents occurred outside built-up areas on highways or motorways and in most cases at higher speeds. Figure 16 shows the distribution of truck speeds immediately before the accident. As the graph

shows, ESP-relevant accidents were only recorded at speeds above 30 kph and were especially frequent in the speed range between 71 and 90 kph (53.4 %).

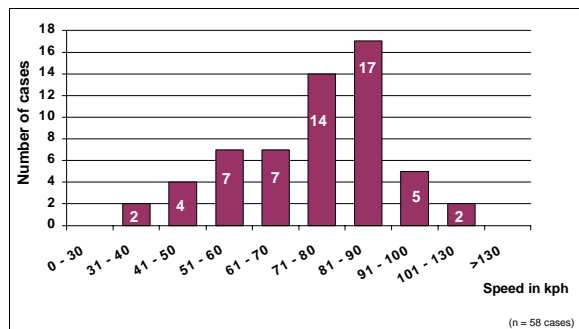


Figure 16. Distribution of truck speeds prior to accidents

Examples

The accidents considered included a very wide range of situations, both within and outside built-up areas. Three typical ESP-relevant accidents are described below by way of example.

Category "excessive speed":

On a wet motorway, a semitrailer with an unevenly distributed load skidded off the carriageway as a result of excessive speed, crashed through the central

crash barrier onto the other carriageway, which was slightly lower, and crushed an oncoming car. Another semitrailer, which had been following the first one, skidded as the driver tried to brake, and collided with another car.

Category "inattentiveness":

The inattentive driver of a light truck failed to notice the end of a tailback forming in front of him, and then attempted to avoid an accident by driving into the gap between his own lane and the oncoming traffic, which was sufficiently wide. The truck skidded, slewing into the end of the stationary traffic and into oncoming traffic, which was already driving as far to the right as possible.

Category "skidding in bends":

Traveling at between 50 and 60 kph, a semitrailer tanker carrying 20,000 liters of hydrochloric acid entered a bend which progressively tightened up. Centrifugal force shifted the center of gravity of the liquid load towards the outside of the bend, causing the truck to overturn as it approached the end of the bend (Figure 17).

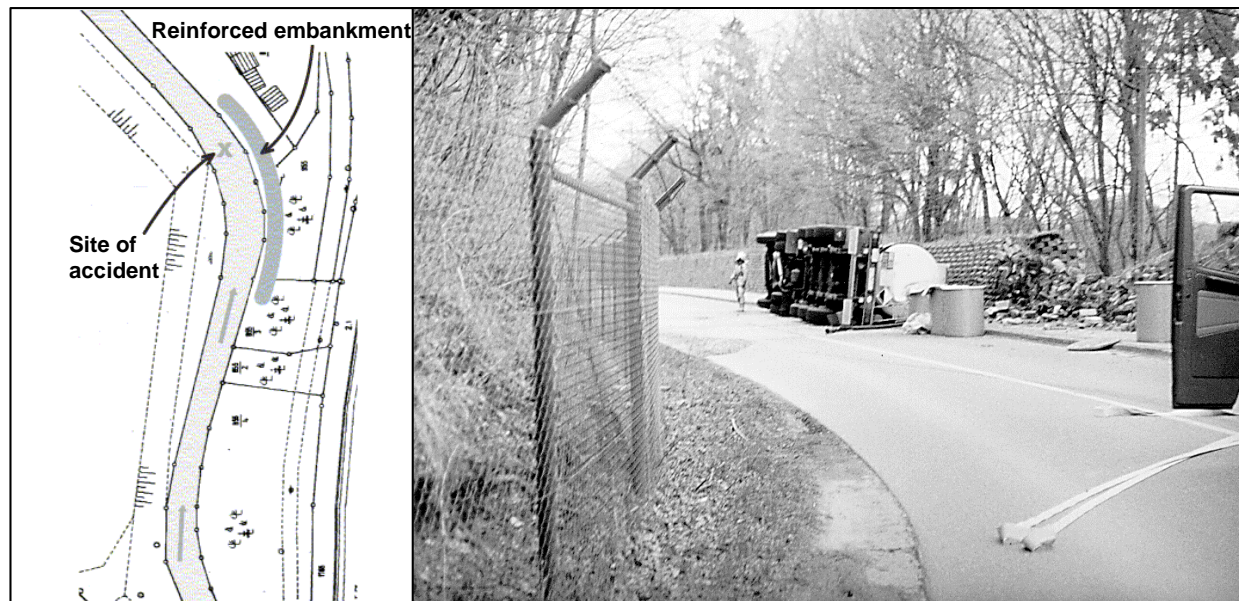


Figure 17. Accident with skidding of a semitrailer in a bend (plan of road and final position of semitrailer at exit of bend)

CONCLUSIONS

Benefits for cars

The real world accident data revealed that car accidents involving a skidding of the vehicle predominate among single accidents (40 to 60 %). Taking the entire car accident occurrence into account, it can be assumed that at least 20-25 % of the accident cases involve skidding.

A major benefit of ESP can be expected for critical situations with skidding of the car in bends where the driver attempts more than one steering corrections. The accident data revealed in this context that predominantly experienced drivers (in approx. 70 % of cases) took action in terms of several steering correction attempts right after the car had started skidding. Particularly here, an ESP intervention can support the driver, thus enhancing the chance of successfully stabilizing the vehicle.

A further benefit can be expected in cases where the car driver does not apply the brakes. In the analysed accident data, a braking maneuver in the pre-crash phase could be observed in only 50 % of the cases. ESP would increase in this case the possibility of lateral stabilization of the vehicle by selective intervention and braking the wheels individually.

Benefits for trucks

A benefit of electronic stability programs, in particular in conjunction with rollover protection, can be expected for commercial vehicles, as well. Thereby, a reduction of up to 9% in the number of serious accidents involving trucks is possible.

Extrapolating the 73 ESP-relevant accidents – by way of an initial approximation – for the whole of Germany, the total number of serious truck accidents which could be positively influenced by ESP would

reach 427 (equivalent to 87 deaths and 456 persons severely injured) (extrapolation factor $100/17.1=5.85$). This study takes no account of accidents resulting in minor injury or "material damage only", which, however, frequently involve substantial financial consequences or have considerable indirect economic consequences, for example as a result of ensuing traffic congestion.

Further research activities will be required to arrive at a more precise quantitative determination of accident avoidance potential. Special attention will need to be paid to trucks carrying hazardous goods, the effects of unsecured loads and driver behavior prior to accidents. In this context, by working closely together, driver assistance system development engineers and accident research scientists can drive forward the optimization of these highly promising systems.

The initial analysis of the effectiveness of the ESP system, based on data from car and truck real world accidents, indicates finally that electronic stability programs offer considerable potential for improving road safety within the bounds of physical feasibility. ESP systems show a significant benefit potential particularly for serious accidents, as they can contribute to the reduction in the number of accidents with skidding by improving directional stability of the vehicle. In view of this considerable potential for accident avoidance and reduction of human suffering in particular - not to mention the substantial economic consequences - and not least with a view to the EU's ambitious target of halving the number of road deaths by 2010, the requirement of the insurance industry is the introduction of ESP systems as standard equipment on new vehicles of all weight categories.

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